

# MASTER OF SCIENCE IN ENGINEERING ACOUSTICS

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## FAR FIELD EXTRAPOLATION TECHNIQUE USING CHIEF ENCLOSING SPHERE DEDUCED PRESSURES AND VELOCITIES

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In this thesis, a technique of extrapolating near field measurement data to achieve device far field performance is undertaken. A Combined Helmholtz Integral Equation Formulation (CHIEF)-defined enclosing sphere placed around an acoustic projector is used to calculate far field response data from near field measurements. Pressure response data at a specified frequency is obtained from a near field linear array. Helmholtz integral relations for the enclosing sphere and integrals of the free-space Green's function and its gradient for defined near field point locations are used along with physical assumptions to form an overdetermined system. The overdetermined system is solved via least squares yielding values of pressure and velocity corresponding to defined locations on the enclosing sphere. The enclosing sphere's values of pressures and velocities are then used with integrals of the free-space Green's function and its gradient to calculate far field response.

**KEYWORDS:** Near Field, Far Field, CHIEF, Least Squares, Combined Helmholtz Integral Equation Formulation, USRD

## CONSTRUCTION AND TESTING OF LOW-NOISE HYDROPHONES

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Several hydrophones have been constructed exploiting the advantages of the MiniCan design. One of them is unamplified and two are amplified. Comparisons of sensitivity, self-noise, size, and price with known and reliable commercial hydrophones yield the following results. The unamplified MiniCan has a sensitivity 22 dB re 1 V/ $\mu$ Pa higher than a Brüel & Kjær (B&K) type 8103 up to 20 KHz and the amplified MiniCans are comparable to their similar and relatively expensive commercial hydrophones. The self-noise level of the amplified MiniCans is significantly lower than those of the B&K 8106 and Reson TC4032. The size of these preamplified MiniCan units is at least 18 times smaller in volume than the largest of the aforementioned. Moreover, the cost of the piezoceramic material and electronics components is around \$30 USD, compared to purchase prices of \$3095 and \$2500 USD for the B&K 8106 and Reson TC4032, respectively. The analysis shows a cheaper and smaller hydrophone, which is more sensitive than a typical hydrophone and has better self-noise than the least noisy commercial hydrophone in the market.

**KEYWORDS:** Hydrophone, Sound Receiver, Transducer

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# ENGINEERING ACOUSTICS

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## **SOURCE/RECEIVER MOTION-INDUCED DOPPLER INFLUENCE ON THE BANDWIDTH OF SINUSOIDAL SIGNALS**

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Most self-propelled vessels moving on, or under, the ocean surface, contain rotating machinery that radiate finite bandwidth signals into the water. Empirical evidence suggests that the signal bandwidth estimated with a far field receiver is often greater than expected. This thesis investigates the use of an acoustic propagation model to predict the received bandwidth of sinusoidal signals when both the source and the receiver are in motion. The bandwidth parameter is calculated from the multi-frequency transmission loss (TL) predicted with a re-written version of K. Smith's Monterey-Miami Parabolic Equation (MMPE) model, including both receiver and source motion. The results for various propagation environments allow exploration of the characteristics of received bandwidth, predicted from sources on the surface or at depth. The dependency of aggregate bandwidth upon conditional parameters such as range, depth, and normalized pressure are also evaluated. In addition to modeling results, this thesis documents a new implementation of the MMPE model for narrowband signals using only the MATLAB programming language. A MATLAB version has the inherent advantages of increased flexibility and portability. A MATLAB implementation of a range dependent ray trace function based upon a Runge-Kutta integration of the eikonal equations is also presented.

**KEYWORDS:** Source, Receiver, Motion, Doppler, Signal, Bandwidth, Parabolic Equation, Acoustic, Propagation, Model

## **UNDERWATER MULTIMODE DIRECTIONAL TRANSDUCER EVALUATION**

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An underwater piezoelectric directional transducer prototype, to be used in underwater acoustic networks, combines different vibration modes of a cylinder to synthesize desired beam patterns. Performance is evaluated in an anechoic water tank, with reference hydrophones and a signal analyzer capable of Fast Fourier Transform (FFT) data processing. An impulse technique is used for measuring impedance, admittance, Transmitted Voltage Response (TVR), Receiving Voltage Sensitivity (RVS), and horizontal and vertical beam patterns. In this technique, a single-cycle tone burst is emitted at a low frequency repetition rate and excites the driving transducer. The signal analyzer excludes the acoustic reverberations from the tank walls by adequate adjusting of the FFT sampling window. Additionally, for beam-pattern data acquisition, a computer simultaneously samples the azimuthal orientation of the prototype relative to a reference hydrophone and the corresponding frequency response, as the evaluated transducer continuously rotates. The FFT capability of the signal analyzer also supports intrinsic noise evaluation. The results show that the new transducer architecture is capable of producing directional beam patterns according to the present operational requirements by electronic control of the internal electrode applied voltage distribution.

**KEYWORDS:** Underwater Acoustics, Underwater Communication, Acoustic Modems, Directional Underwater Transducers, Piezoelectric Transducers, Acoustic Measurements, FFT Data Processing